# The concept of biological control

Natural biocontrol results when naturally occurring enemies keep pest infestation at a lower level than would occur without them, and is inherent in natural biodiversity. Birds, bats, insects, fungi, bacteria and viruses all play a role as predators and parasites in the web of life.

**Biological control** is, generally, man's use of a specially chosen living organism to control a particular pest, and is a form of manipulating nature to increase a desired effect. The chosen organism can be a predator, parasite or pathogen, which will attack the harmful pest. All animals or plants have natural enemies (predators, parasites, pathogens or competitors) that prevent their uncontrolled proliferation. Natural populations of predators (e.g. lady beetles, lace-wings, syrphid flies, preying mantids, wasps, predaceous mites) and parasites (e.g. wasps, tachinid flies, nematodes) are valuable in reducing infestations of pests. Usually, however, some level of pest infestation must be tolerated to attract and maintain natural adversarial populations.
Biological control uses precisely these "natural enemies" to maintain phytophagous pest populations within acceptable limits and to consequently increase the number of species in the agroecosystem, which becomes more complex and stable.

**Evolution of biological control**
The first example of biological control dates back to the end of nineteenth century, when Californian citrus orchards had suffered attacks from the Australian scale, *Icerya purchasi*.
This scale was successfully controlled with the introduction of its natural enemy, the coccinellid *Rodolia cardinalis.* In Russia at around the same time, the fungus *Metarhizium anisopliae* was used for the control of *Anisoplia austriaca*, a cereal beetle parasite.
In the first half of the twentieth century, the lack of sufficient theoretical basis supporting these early efforts resulted in limited development of biological control techniques. Another halt in this development came in the 1950s with the success of chemical control methods.
Recently, however, second thoughts on the use of chemistry in agriculture, greater "environmental consciousness" and improved theoretical knowledge have all boosted biological control techniques.

**Types of biological control agents**
Insects, mites, nematodes and microorganisms are natural enemies of phytophagous insects and are used in biological control. Each of these organisms has a different relationship with the harmful insects:

- **Entomophagous insects.** Entomophagous insects are the main agents used in biological control. They are classed as either predators or parasitoids, each with completely different characteristics contributing to their effectiveness as biological control agents.
- **Predators**. These are organisms which attack and feed on a number of individuals of the pest. Some of them (e.g. phytoseids, mirids, coccinelids, and antocorids) are predators throughout their entire life cycle while others are so in the larval stage only. Predators are subdivided into:
    - Specialist predators, which live on one or on a small number of species
    - General (polyphagous) predators, which can live on several species

The polyphagous species are considered less suitable than monophagous species, because they

are less likely to concentrate feeding on pest species in the presence of an abundant alternative predator. However, in general, predators have the advantage over parasitoids in that each individual consumes a number of prey during their lifetime and, unlike parasitoids, that immature stages are also actively searching for and consuming pests. Among the most common predators of insect pests are beetles, predatory bugs, crysopids and the syrphid larvae.

- • **Parasitoids.** Parasitoids are parasitic in their immature stages, when the larvae develop within (endoparasites) or on (ectoparasites) a host and result in its death. Individual parasitoids consume only one host during development of adults, which are free-living and usually feed on pollen, nectar, honeydew or even the body fluids of their host.

As a group, parasitoids belong to Hymenoptera and Diptera and exhibit a wide range of hosts specialties and habits. Host-specific parasitoids are considered most suitable for use in biological control.

**Pathogens, including bacteria, viruses, fungi, protozoa and parasites (particularly nematodes)**

- **True parasites**, such as **parasitic nematodes**, differ from parasitoids in that they do not kill their host, merely debilitate it. Despite this, parasites have proved useful as control agents, to the extent that a number of commercial companies involved in the culture and sale of nematodes for the control of garden and horticultural pests now exist.
- **Parasitic pathogens (bacteria, viruses, fungi)** will often kill their host outright and then liberate millions of spores or 'resting stages' which are dispersed to infect other host individuals. Their relative pathogenicity, high growth rate and, in some, ease of culturing ensure their use in both augmentation and inundating releases. Pathogens may also act as biocontrol agents through competitive exclusion or through the production of antibiotics. Known as antagonists, they are particularly useful in the biological control of plant pathogens.
- **Competitors** are organisms which compete with the pathogenic agent for colonization of a part of the plant, leaving the plant damage undamaged in the process. Competitors are typically fungi which compete with other fungi. In some cases, e.g. the chestnut tree canker (*Endothia parasitica*), they are hypovirulent strains of the same parasitic fungus.

**Other biological control agents**

One final group that deserves mention is **vertebrate biological control agents.**

Although, in general, vertebrates are too polyphagous for use in biological control, they have been found useful as a means of pest control on a number of occasions.

Other biological control methods to be considered are those based on the use of pheromones (i.e. mass capture traps, sexual confusion) and are described in other units.

**Factors affecting the activity of biological control agents**

A number of factors are to be considered in affecting the activity of organisms used in biological control. Such factors include:

- Characteristics of the pest, including type of damage they cause, mobility, reproductive rate and dissemination efficiency.
- Characteristics of the cropping system that may influence the likelihood of success in introduction, augmentation, inoculation and the use of microbial insecticides. These characteristics can be considered under climate, crop duration, scale of planting and

cultural/agronomic practices.

- Natural enemy/prey interactions and the density of host dependence.
- Weather and environmental conditions.

Like those of pests, populations of natural enemies are subject to a number of factors which limit their activity. In order to forecast the effectiveness of a control intervention, it is therefore necessary to know the needs and characteristics of the pest and its natural enemy.

**Applied biological control**

Applied biological control occurs when the farmer supplements populations of beneficial organisms through periodic releases of parasitoids, predators or pathogens and can often be effective. In codling moth control, for example, well-timed inundating releases of beneficial organisms, e.g. *Trichogramma* egg parasitoids, are used. Most beneficial organisms used in applied biological control today are insect parasitoids and predators; they control a wide range of pests from caterpillars to mites.

Information about rates and timing of release are available from suppliers of beneficial organisms. It is important to remember that released insects are mobile and are likely to leave a site if the habitat is not conducive to their survival. Many applied biocontrol organisms will benefit from food, nectar and/or pollen sources.

**Biological control strategies**

There are five different types of biological control strategies:

**Introduction.** Biological control through introduction is most frequently used against introduced pests which arrive in a new area and become permanently established without an associated natural enemy complex. Introduction aims at reaching a fixed presence of a specific enemy in the environment. For this reason, it cannot limit itself to the introduction of the natural enemy species but must also foresee all strategies for encouraging its survival and diffusion.

Aside from the previously cited *Rodolia cardinalis*, the most famous examples of this technique's application are the control of *Eriosoma lanigerum* through the introduction of its specific parasitoid *Aphelinus mali* and that of *Quadraspidiotus perniciosus* through the introduction of *Prospaltella perniciosi*.

When a natural enemy is introduced in classic biological control, it should, if upon establishing itself, reduce the pest's abundance to a level below the pre-introduction population size.

After an initial phase of rapid reduction in the harmful insect population and equally as rapid growth of the natural enemy population, a long period of equilibrium generally follows. In successful introduction, the new population level will be well below the economic damage threshold.

Where successful, this traditional use of biological control offers permanent levels of control with few risks associated with it and, above all, a very cost-effective solution.

Classic biological control has been most successful with pests endemic to fruit, forest and range crops, where the perennial nature of the crop permits continuous interaction between natural enemy and host without the ecological upheavals associated with management of annual crops.

**Augmentative control.** This strategy tends to be used in situations where natural enemies are absent or population levels are too low to be effective, so numbers are augmented by the use of laboratory-cultured natural enemies. The augmentation method relies upon continuous human management and, unlike the importation and conservation approaches, is not a permanent

solution.

**Inoculation.** Inoculation is used in cases where a native natural enemy is absent from a particular area, or an introduced species is unable to survive permanently. Inoculative releases are made at the beginning of the season to achieve seasonal control, i.e. to colonize the area for the duration of the season or crop and thus prevent pest build-up.

**Inundation.** Releases made with biological control through inundation involve very large numbers of native or introduced natural enemies, in a way similar to the application of chemical pesticides. The natural enemy is usually a pathogen and is often formulated so that it can be applied using conventional pesticide spray equipment. Sometimes used as substitutes for chemical pesticides, inundative control agents are applied for short-term control when pest populations reach damaging levels.
This technique is specifically in greenhouses because of its relatively elevated costs. Additionally, greenhouses are circumscribed places in which control of exogenous factors determining the success of the intervention is easier.
The most successful agent in this category is the bacterium *Bacillus thuringiensis* used to control pests such as lepidopteran, dipteran and coleoptera, although other entomopathogens based on fungi and viruses have also found niches.

Conservation of natural enemies is a key aspect of any biological control effort. This involves identifying any factors that limit the effectiveness of a particular natural enemy and changing them to aid the beneficial species. Conservation of natural enemies involves either reduction factors that interfere with natural enemies or provision of necessary resources. It is probably more productive to provide good conditions for natural population growth of control organisms than to introduce exotics.
Natural populations of predators (e.g. lady beetles, lace-wings, syrphid flies, preying mantids, wasps, predaceous mites) and parasites (e.g., wasps, tachinid flies, nematodes) are valuable in reducing pest infestation. However, some level of infestation must usually be tolerated to attract and maintain natural enemy populations.
Reduction in pesticide use may in some cases be sufficient to encourage growth of natural enemy populations to levels where they can exert sufficient levels of pest control. In other situations, it may be necessary to take more active steps to encourage natural enemies. Habitat enhancement for beneficial insects, for example, focuses on the establishment of flowering annual or perennial plants that provide pollen and nectar needed during certain parts of the life cycle. Other needs include water, alternative prey, perching sites, overwintering sites and protection from wind. Beneficial insects should be viewed as a type of mini-livestock, with specific habitat and nutritive needs to be included in farm planning.
The success of such efforts depends on knowledge of the pests and beneficial organisms within the cropping system. Where do the pests and beneficials overwinter? What plants are hosts and non-hosts? By incorporating this knowledge into planning, the ecological balance can be manipulated in favor of beneficials.

**Sterile insect technique (SIT)**

Autocid control has had very satisfactory results, but it can only be used on a vast scale and in the presence of very particular environmental conditions. The goal is to impede reproduction of the infesting species by introducing an adequate number of sterile individuals into the environment.

For the technique to be successfully applied, the following conditions must be satisfied:

- The initial population density to be controlled must be relatively small;
- the species must mate only once;
- the total population must be included; this condition exists with very large-scale treatments or in circumscribed and isolated environments (e.g. islands).

To be applicable, these techniques require an elevated number of insects or mites and consequently the need to resort to "biofactories" for their finding.
Before carrying out any biological control intervention, a careful monitoring of the crop's state and of the presence of parasites is necessary. In particular, it is necessary to recognize one or more pests present on the crop (because the natural enemies' specialization is often elevated) very precisely and to give special attention to environmental conditions. In this way it will be possible to:

- choose the most appropriate natural enemy of the pest to be controlled and the environmental conditions;
- determine the best time to launch or introduce a natural enemy;
- estimate the optimal quantity of helpers to be introduced in relation to conditions of the environment and infestation.

**Microbial control**
The use of pathogens or parasites to control pests is also called microbial control. Unlike mites and insects, antagonist microorganisms rarely reproduce in the environment, thereby creating stable populations. Because of this, they must be considered and dealt with as "biological insecticides" in the field.
The most famous and diffused pathogenic microorganism is *Bacillus thuringiensis*, an aerobic spore-forming bacterium, of which various strains are available (e.g. *kurstaki, aizawai, israeliensis* and *tenebrionis*). These strains differ in the specificity of their activity on lepidopterous larvae (the first two strains are specific to these), on some mosquito larvae (in the third) and on *Leptinotarsa decemlineata* larvae (in the last).
During sporulation, the microorganism produces a toxin that interacts with the glycoproteins of the insect's intestinal cells, blocking digestive muscles apparatus and interrupting the nutritional process.
In commercial products, usually only the toxin which acts exclusively through ingestion is present. To be effective, it is therefore necessary that the insect feeds for some time on the treated plant.
The selectivity of *Bacillus thuringiensis* is very high and it is fully effective when used in the early larval stages.
Many extremely specific entomopathogenic viruses are known. They generally infect the insect when in the larval stage and act through ingestion. Their action is not immediate, and infected insects can still feed for some time, causing further damage.
Granulosis is the most commonly used virus and is active on *Cydia pomonella*. Other microorganisms effective on different phytophagous insect species are also available.

**Fungi and nematodes**
Fungi pathogenic on insects, mites and other fungi are characterized by the ability to actively penetrate the arthropod's body through the cuticle or another orifice. Therefore, they operate by contact and can infect phytophagous insects regardless of feeding habits or age, causing death

through the activity of the mycelium or other toxins produced.
Relative humidity is the most important factor affecting fungal activity. During the infection period, relative humidity must be close to 100%. For some species, a film of water is also required to limit the use of fungi against epigeous parasites, which can handle high relative humidity rates without exposure to the attacks of cryptogams. The control of terrestrial insects is less problematic.
The most frequently used **nematodes** in biological control are of the genera *Steinernema* (*Neoaplectana*) and *Heterorhabditis* and can efficiently control larvae of *Othiorrhinchus sulcatus* and sciarids diptera. They operate via direct contact, as they are able to infect the host through the cuticle or other orifices, and their harmful effect on insects is related strictly to their symbiosis with bacteria belonging to the genera *Xenorhabdus.* Once these bacteria are released inside the host, they provoke its death by septicemia.
The nematodes' activity is strongly related to the sensitivity to drying out and to UV rays, which in turn are strongly recommended for the containment of terrestrial insects.
The conditions which must be created for the use of fungal parasites and competitors and of nematode parasites are such that practical applications are for the moment very limited.